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IoT-Based Weather Monitoring Station

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Abstract : Because of global climate changes, geospatial monitoring and weather evaluation has become very crucial for a number of spheres such as agriculture, environmental studies, disaster management, and urban planning. In this work, an IoT-based system for weather forecasting which is designed for on site and real-time field data retrieval, particularly suitable for small or impaired areas is presented. The novelty of the proposed system depends on the connection of cheap sensors through an ESP8266 microcontroller used to measure relevant climatic variables such as temperature, humidity, and atmospheric pressure. The information is relayed to a cloud platform from where the users access it using an online platform. The system is conveniently cheaper, easy expand and modify, unlike the traditional weather stations which are often expensive and difficult to maintain for small applications. This IoT system gives the chance of permanent reminder about the weather and its changes over time, which is of great assistance when making business decisions from the agricultural sphere to the geography of natural disasters. The findings from this research elaborate on the possibilities of IoT technology in the development of complex, flexible, and effective weather monitoring structures that are simple for use by local communities.

Keywords: **IoT, weather monitoring, ESP8266, real-time data, cloud storage, small-scale applications, environmental data acquisition.**

1. Introduction:

Many sectors in agriculture, transportation, urban planning, and emergency management require accurate and timely information about the weather. Weather monitoring systems traditionally depend on complex, large-scale infrastructures involving satellites, radar systems, and data

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centres. These systems are highly effective on a broad scale but often very expensive to maintain and operate, 1 mainly in smaller regions with limited resources or infrastructure. The high cost and operational complexity of traditional weather systems act as a barrier for the smaller communities, institutions, and local governments that would like to have localized information about the weather to aid in decision-making. Environmental monitoring has been recently influenced by the Internet of Things (IoT). It is possible to collect and transfer data in real-time across a network at low cost by using IoT technology, thus being scalable for continuous monitoring in resource-limited setups. The ability to capture high frequency, high-accuracy data on temperature, humidity, and atmospheric pressure through IoT and sensor technologies can allow for access to immediate data analysis, which is useful in agricultural applications. For instance, real-time data can facilitate decision-making regarding irrigation, planting, and pest management that might lead to higher crop yields and reduced wastage of resources. A multi sensor IoT-based weather monitoring system tailored for small areas tracking key environmental parameters utilizing data from an ESP8266 microcontroller is being put forward. Data shall then be transmitted to the respective cloud platform, thus putting it into storage that one will access via a very easy interface on the web, much unlike other systems intended to execute large-scale applications but expensive with demanding configurations that require high maintenance processes. This system may be able to empower smaller regions to track the weather pattern independently and reliably, and better plan for and respond to environmental conditions by providing an affordable localized solution. The paper is organized with a Literature Review section giving an overview of existing weather monitoring systems and related IoT applications. The Proposed System section discusses the architecture and design choices with a special focus on sensors and a microcontroller that would result in real-time data monitoring. The Methodology covers the process of data collection and cloud integration. In the Conclusion, the benefits that IoT-based monitoring brings to the small regions are summarized along with directions for future work.

2. Literature Review:

In recent years, IoT-based weather monitoring systems have received immense attention. Several studies have established that IoT technologies are not only efficient but also economical for collecting and analysing environmental data. Traditional weather monitoring relies on large-scale infrastructure that is expensive and unaffordable for smaller regions or low-resource settings. Researchers have 2 explored alternative options in the use of IoT, which provide affordable scalable systems for weather data collection. They work to address the limitations of the previous systems. In particular, Sabugar [1] designed an IoT-based monitoring system that integrates sensors connected with a microcontroller towards measuring weather parameters such as temperature and humidity. As an advantage, this storage allows for real-time assessment from the cloud, in view of applications in different aspects of agriculture and disasters. Another low-cost IoT-based weather monitoring system based on Raspberry Pi was introduced by Shende et al. [2]. This reveals that low-cost IoT can indeed provide real-time precise data of weather to end users. Various studies note that IoT platforms such as Thing Speak and Firebase that offer data visualization and data storage abilities. Such IoT platforms increasingly use for providing real-time access of data to end-user users via mobile apps and a web interface [3]. Another study by Khan et al. [4] elaborated on how machine learning could be integrated into IoT based monitoring systems to improve the accuracy of weather prediction They demonstrated better accuracy with the help of IoT sensors and data analytics. Improving the accuracy of forecasts is indispensable for sectors that require timeliness in weather information, such as agriculture and aquaculture. Nevertheless, the existing literature highlights drawbacks in IoT-based weather monitoring systems. Limitations pertaining to connectivity, data security, and sensor accuracy are among such drawbacks [5]. Still, recent studies have brought new hope by improving accuracy via advanced calibration methods, effective data encryption, and optimised sensor networks [6]. The current paper builds upon these already existing solutions, by proposing a localized low-cost weather monitoring system tailored for small regions, and offering an easily accessible and practical tool for the collection of localized environmental data.

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3. Proposed Model:

The proposed weather station is an IoT-based solution that gives real-time monitoring of environmental conditions, particularly targeting parameters like temperature, humidity, and ambient light intensity. It is a low-cost, highly accessible station, built using a compact yet powerful NodeMCU microcontroller as the central processing unit. It also uses a DHT11 sensor to monitor temperatures and humidity levels, as well as an LDR sensor to detect the levels of ambient light, along with a 2x16 LCD that makes use of an I2C module to effectively display all data. By making use of the I2C protocol, the design makes fewer connections between the devices involved, hence simplifying both circuitry and its assembly. This not only reduces hardware complexity but also frees GPIO pins on the NodeMCU for possible future expansions. Integration with these sensors on the NodeMCU allows for easy data acquisition and processing while providing the I2C LCD as an intuitive real-time display of environmental data. The system is scalable, with easy addition of more sensors, and it can be powered by a 5V USB supply or upgraded with solar power for remote or off-grid deployment. NodeMCU (ESP8266): NodeMCU acts as the main microcontroller that manages data acquisition, processing, and display. It is suitable for IoT applications and future expansion, such as cloud-based data storage. The sensor data is read through the GPIO pins, processed, and then transmitted to the LCD for real-time display.

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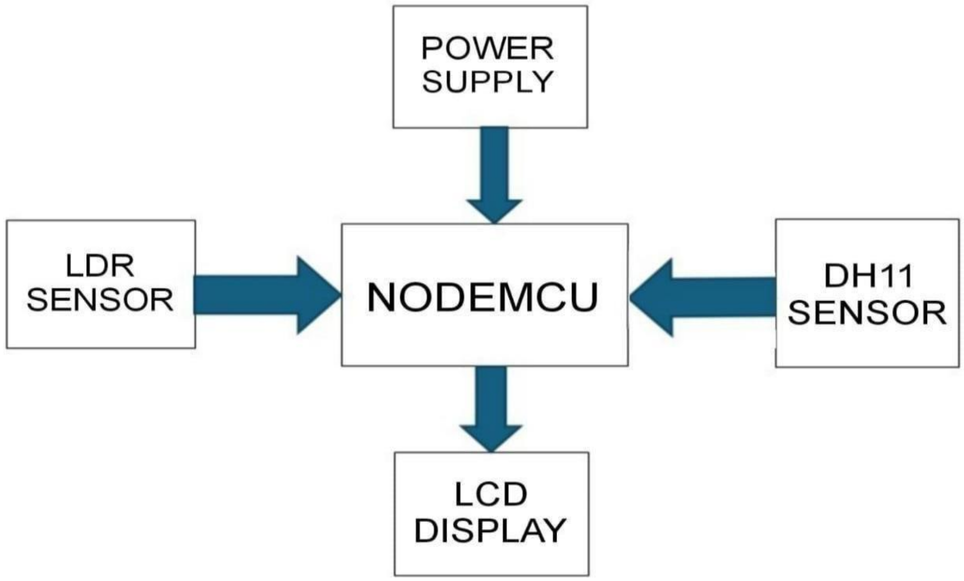

Figure 1: Block Diagram of IoT-Based Weather Monitoring System

DHT11 Sensor (Temperature and Humidity): The DHT11 sensor is a cheap digital sensor that can be used to measure temperature and humidity with a reasonable level of accuracy for simple weather monitoring. It offers a temperature range of 0-50°C and a humidity range of 20-90% connected to a digital pin on the NodeMCU for real-time data capture. The sensor's data is processed and displayed as both temperature and humidity readings.

LDR Sensor: It is a Light Intensity sensor that measures ambient light intensity. The sensor is connected to the NodeMCU's analog input pin, where it feeds in voltage readings varying according to the light level. The NodeMCU processes these readings, converting them into light intensity values displayed on the LCD.

LCD Display (2x16 with I2C Module): The collected data is displayed using a 2x16 LCD with an I2C module. Utilizing the I2C interface saves the NodeMCU's GPIO pins as only SDA and SCL connections are required. Real-time data on temperature, humidity, and light intensity are displayed on the LCD, which makes the weather station user-friendly without any additional hardware for accessing data.Power Supply **:** The weather station is powered through a 5V USB

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source, which ensures stable operation. Future iterations could incorporate battery backup or solar power for Deployment in remote areas, therefore makes the system more versatile. It is possible for expansion in this modular design easily using additional sensors and it adapts the weather station for environmental monitoring applications comprehensively.

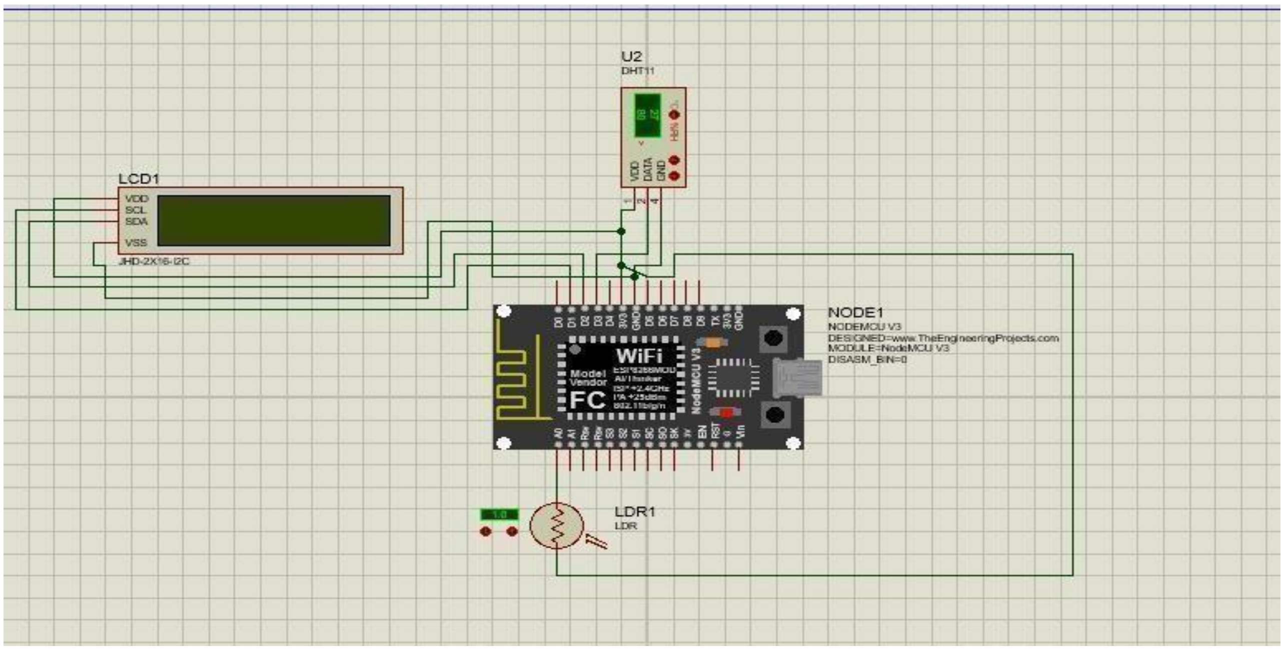

Figure 2: Proteous Design of IoT-Based Weather Monitoring System

Figure 2 Circuit diagram for weather station with NodeMCU Microcontroller, DHT11 temperature and humidity sensor, LDR (Light Dependent Resistor), 16x2 LCD I2C interface. It can be seen that the NodeMCU is the main processor that reads data from various sensors connected to it and displays the results on an LCD. The DHT11 sensor measures temperature and humidity. It is connected to one of the digital pins of the NodeMCU for data communication. Its power and ground pins are also connected to the NodeMCU.

It calculates the light intensity in the ambient. There is a voltage divider circuit connecting LDR to analog input pin A0 on the NodeMCU using a pull-down resistor. This LCD module has an I2C module so is relatively easy to communicate as two wires are used: one for SDA, and the other for

SCL, connected to D2 and D1 on NodeMCU, respectively. It accepts all the processed data from the NodeMCU and displays the real-time temperature, humidity, and light intensity. It supplies power to all components through the VCC and GND pins of the NodeMCU. In this setup, efficient weather monitoring is possible by incorporating environmental sensing and user-friendly output display.

4. Result:

The weather station was exposed to various indoor and outdoor conditions to test how different parts functioned. Each part worked smoothly in taking, processing, and display without delay. It may be useful for remote monitoring; it has Wi-Fi included but is displaying data locally in the current version. It has an average response time within 2 seconds when taking measurements for temperature and humidity with the DHT11 sensor. Suitable for basic weather monitoring. LDR sensor did well with light measurements: there is visible change under varying light sources, but in low-light conditions, the precision decreases. The 2x16 LCD display was connected to the I2C module and displayed the temperature, humidity, and light levels in real-time with hardly any lag. It also took fewer pins and was pretty reliable on NodeMCU. Overall, the weather station provides reliable, timely environmental data with low power consumption and thus a good solution for continuous monitoring. Its design also accommodates future enhancements like the addition of sensors for rain, wind, or air quality. The station can also be expanded to include wireless data logging and remote access, which enables real-time data analysis and cloud integration. This makes it useful for agriculture, environmental management, and disaster preparedness.

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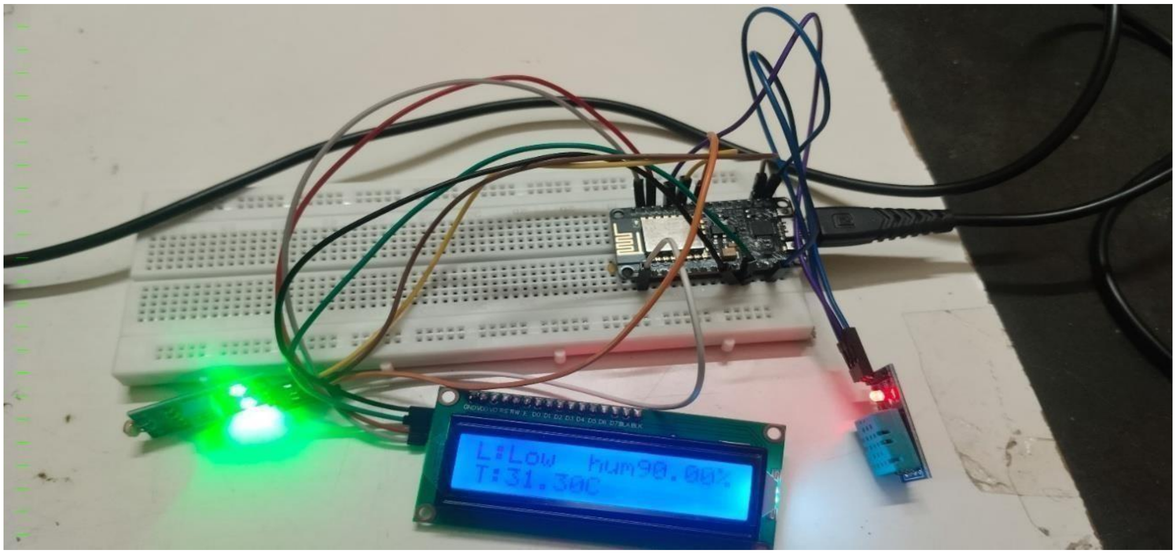

Figure 3 : Design of IoT-Based Weather Monitoring System

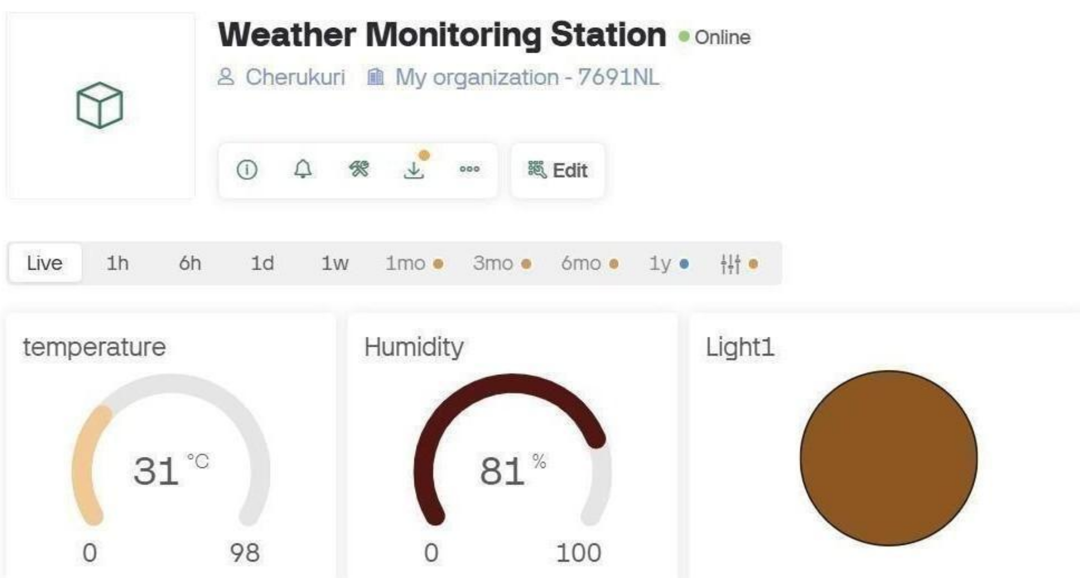

Figure 4: Weather Monitoring on web through Blynk app

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5. Conclusion:

This research introduces a low-cost IoT-based smart weather station for real-time environmental monitoring in small regions. This system efficiently acquires and transmits data by the use of sensors like the DHT11 for temperature and humidity, LDR for light intensity. Contrary to traditional weather stations that require huge resources, this accessible solution can be used by small communities, farms, and individual users. Field tests indicate that its temperature and humidity readings are deviated by less than 5% compared to those of conventional stations. Real-time data transmission through MQTT along with a web-based dashboard improves decision-making in agriculture and disaster management. Optimizing irrigation and harvesting for farmers and monitoring the trend of weather for emergency teams form part of the application. The modular design will be useful for future expansion, including additional sensors for soil moisture and air quality and the integration of machine learning models to analyze historical data for weather forecasting. This way, it can provide a scalable and sustainable solution to the challenges that arise due to weather.

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